THE MODERN BEE AND WASP ASSEMBLAGES (HYMENOPTERA: ACULEATA) OF WARWICKSHIRE'S CALCAREOUS QUARRIES AND SPOILHEAPS, AND THE CONSERVATION ISSUES FACING THEM

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Abstract

A comparative review of the modern bee and wasp assemblages (Hymenoptera: Aculeata) of fourteen calcareous (mudstone, limestone and ironstone) quarries and spoilheaps in Warwickshire is given. The sites were assessed in terms of species diversity, presence of rare species and the quality of various habitat-related assemblages such as calcicoles. 186 species were recorded in total during the main study period from 1990–2002, and the best site (the Bishops Bowl–Bishops Hill Complex) produced a list of 128 species. Notes on some of the scarcer species are provided and discussion of the main conservation issues that affect bees and wasps at these sites. The danger of placing too much emphasis on Species Quality Indices is highlighted.

Introduction

Geologically speaking, Watsonian Warwickshire is a county of two halves. The north and west is largely underlain by pre-Jurassic mudstone, sandstone and igneous rocks overlain by much younger glacial drift that mostly give rise to base-poor soils. These soils once supported scattered heathland within a setting that remained heavily wooded until relatively late, representing the legendary 'Forest of Arden' which is now classified as 'Ancient Arden' by the Warwickshire Landscape Guidelines (Warwickshire County Council, 1993 parts 1–3) and forming part of the Midlands Plateau Natural Area. Today this part of Warwickshire has lost most of its heathland and bog, but still supports a variety of acidophilous or calcifugous plants and insects which occur predominantly or exclusively within this part of the county.

By contrast, the south and east is largely underlain by mudstone and limestones of Jurassic age, with a scattered drift cover. The Jurassic succession includes a narrow ironstone unit (the Marlstone) that forms some of the escarpments along the northern edge of the Cotswolds such as Edge Hill, plus several large outlying hills just north of the Cotswolds. The underlying geology of southern and eastern Warwickshire has given rise to more fertile, calcareous soils, mostly within the landscape zone known as the 'Feldon', which falls within the Midland Clay Pasture Natural Area. This had largely been cleared of its woodland by the time the Romans arrived, and it is likely that calcareous grasslands were widespread here over many centuries within a landscape of open field systems and grazed hillsides. During the twentieth century, most of the species-rich grassland here was lost. Today, perhaps as little as 50 ha of 'unimproved' ancient limestone grassland remains and most of it is fairly unimpressive in entomological terms.

Fortunately, the various underlying deposits of this area have been exposed through quarrying and the production of cuttings for the local road, railway and canal networks. The quarries in particular display widely varying characters and ages and now collectively support a diverse array of calcareous conditions with many

unusual plants and insects found nowhere else in the County. Calcareous spoilheaps are associated with some of these quarries and are sometimes more interesting than the quarries themselves. A few spoilheaps have also been produced following excavation of railway cuttings through limestone hills during the nineteenth century. The largest of these, Harbury Spoilbank, is included in this review.

Yet, in spite of the fact that some of the sites covered in this paper are amongst the most important calcareous sites in the entire British Midlands and some of the most interesting wildlife sites in Warwickshire, they experience a disproportionate level of threat. This includes the two sites that score highest for bees, wasps, butterflies and a range of other insects. These are not Sites of Special Scientific Interest (SSSIs), whilst lesser sites, often somewhat degraded through the effects of succession, are. It was this in mind that the author set out to collate detailed and reasonably comparative data for a variety of insect groups at fourteen of the potentially best calcareous sites in the county. The following paper concentrates on the bee and wasp information obtained, extending the published information on the aculeates of calcareous habitats furnished by publications such as Archer (1997) and Alexander (2003).

The geological deposits covered

(i) White Lias – the oldest (late Triassic) and most northerly of the important calcareous deposits in Warwickshire, stretching obliquely across the county from the Stour Valley in the south to near Rugby in the east. The White Lias comprises up to 2 metres of hard, fine-grained limestone that was once a popular building stone obtained from a small number of shallow quarries. White Lias can give rise to strongly calcareous habitats with many unusual calcicoles and the clay component can lead to the formation of wetlands and seasonal water-logging.

(ii) Wilmcote Limestone – a fine-grained late Triassic – early Jurassic limestone historically quarried from a few sites west of Stratford and also giving rise to strongly calcareous conditions.

(iii) Blue Lias – an early Jurassic deposit underlying much of southern and eastern Warwickshire. It comprises alternating beds of mudstone and fine-grained muddy limestone which has been exploited by the cement industry, resulting in several very large quarries and cement works, one of which (Rugby Works) is still operated by the company RMC Group PLC. Blue Lias produces a strongly calcareous soil prone to intense drying out in dry summers, but also capable of producing some fine wetlands and seasonally flooded areas.

(iv) Marlstone – a hard, tawny-coloured 'ironstone' of early Jurassic age that forms the famous 'Hornton Stone' so characteristic of the architecture along the northern edge of the Cotswolds. Several large, shallow quarries exist in the Edge Hill district and can give rise to a mildly calcareous habitat that lacks the floristic diversity and large number of calcicolous plants typically associated with the Lias quarries. The ironstone was also used as a source of ferrous oxide in medieval times, being obtained from shallow quarries on various hill tops in the same general area. This has resulted in some very uneven landforms, most of which are grassed-over agriculturally improved sheep pasture not covered by this paper.

(v) Middle Jurassic limestone – quarried most recently at Cross Hands Quarry at the southern tip of the county. The Middle Jurassic succession includes oolitic building stones such as the Chipping Norton Limestones, chalkier, less hardy stone such as Clypeus Grit, and substantial layers of mudstone and sandstone.

The limestones give rise to a more distinctly calcareous habitat than Hornton Stone, with many of the unusual calcicoles associated with Lias sites, though they do not easily produce wetlands.

The survey sites

Fourteen sites are considered, plus a combined list for Sites 2 and 3, which are immediately adjacent to one another and best considered as a single ecological unit (though traditionally they have been treated separately). A brief description of each site is given, plus the dates of visits. Dates in brackets refer to relatively short visits or visits in sub-optimal weather.

1. Avon Hill Quarry (AH) SP416505 – a medium-sized ironstone and sandstone quarry with patches of species-rich grassland, tall herb, wetland (with seasonal water bodies, swamp and carr) and extensive patches of ruderal habitat maintained by regular four-wheel drive meetings. Dates of visits: 14.iii.1997, 15.viii.2001, 30.iii.2002, 19.iv.2002, 1.vi.2002, 6.vii.2002, 2.ix.2002, 19.x.2002.
2. Bishops Bowl (BB) SP385588 (Fig. 1) – a large Blue Lias quarry system created by the cement industry with a complex mosaic of species-rich calcareous grasslands, tall herb, several permanent water bodies (supporting commercial fishing), assorted wetlands and dense scrub/secondary woodland. Dates of visits: 10.iv.1992, 7.v.2001, (8.v.2001), 11.vi.2001, 23.vii.2001, 27.vii.2001, 29.iii.2002, 21.iv.2002, 8.vi.2002, (12.vii.2002), 12.viii.2002, 13.ix.2002.
3. Bishops Hill (BH) SP393585 – the large spoilheap and former works directly east of the previous site, now supporting species-rich grassland, tall herb and ruderal habitats plus extensive scrub and secondary woodland and a single small quarry. The site was extensively bulldozed in the late 1980s but has become flower-rich since. Dates of visits: 19.vi.1993, 17.ix.1993, 20.iv.1994, 31.v.1994, 9.iv.1995, 30.iii.1997, 25.vii.1998, 8.v.2001, 25.v.2001, 30.viii.2001, 30.vi.2002, 18.x.2002.
   Bishops Bowl + Bishops Hill (BB + BH) – the combined lists of the previous two sites, which are best treated as a single ecological unit for evaluation and designation purposes.
4. Cross Hands Quarry (CH) SP269290 (both sides of A44 road) – a pair of medium-sized Middle Jurassic limestone quarries which form the southern tip of Warwickshire, supporting species-rich calcareous grassland, scrub and ruderal habitat. The larger quarry at the east (which includes a small geological SSSI) has largely been land-filled since the mid 1990s and lost much of its original interest. Dates of visits: 19.iii.1995, 4.iv.1995, 28.vi.1995, 27.iv.1996, 31.viii.1996, (6.iv.2002), 5.v.2002, 1.vii.2002, 21.ix.2002.
5. Gypsy Hall (Wilmcote) Quarry (GH) SP152592 – a medium-sized Wilmcote Limestone quarry containing a small geological SSSI, with species-rich calcareous grassland and surrounding scrub. Dates of visits: 24.vii.1999, 5.iv.2002, 3.v.2002, 17.vi.2002, 16.vii.2002.
6. Harbury Spoilbank (HS) SP385598 – a fairly small 6.7 ha site supporting a mixture of species-rich calcareous grassland and tall herbs, with areas of dense scrub. Formed on a long hillock of Blue Lias spoil resulting from construction of the adjacent Leamington Spa to Oxford Railway line through an adjacent cutting in the 1840s. Part of a larger SSSI (Harbury Railway Cutting SSSI) now managed by Warwickshire Wildlife Trust. Dates of visits: 10.iv.1992, 13.vii.1997, 12.iv.2002, 12.v.2002, 12.vi.2002, 3.viii.2002, 14.viii.2002.

7. Lighthorne Quarry (LQ) SP324558 – a small shallow White Lias quarry with some established calcareous grassland, sparsely-vegetated scree, several temporary pools and patches of grey willow. No formal management, but occasional sheep grazing. Dates of visits: 24.vi.1999, 7.vii.1999, 14.viii.2001, 26.iii.2002, (5.iv.2002), 4.v.2002, 1.ix.2002.
8. Napton Quarry (Na) SP455613 – a large quarry system on the west side of Napton Hill consisting of a very old ironstone quarry at the top (containing a geological SSSI) and younger, but abandoned, brick works at the bottom. These collectively support much improved pasture, wetlands of various sorts (including pools, swamp, carr and spring-fed seepages), and ruderal/tall herb habitats. Dates of visits: 22.viii.1995, 5.iv.1996, 21.iv.1996, 13.vi.1996, 11.ix.1999, 7.iv.2002, 5.v.2002, 28.vi.2002, 24.vii.2002, 22.ix.2002.
9. Nelsons Quarry (Nel) SP443642 (Fig. 2) – a deep Blue Lias quarry with large spoilheaps supporting calcareous grassland, ruderal habitat, scrub, several water bodies with surrounding swamp and reedbeds, secondary woodland and a large seepage system. Part of a larger SSSI (Stockton Quarries and Cutting SSSI) also containing Stockton Cutting. Dates of visits: 12.vi.1994, 9.iv.1995, 13.iv.2002, 13.v.2002, 13.vii.2002, 21.viii.2002.
10. Newbold Quarry LNR (New) SP494769 – another deep, water-filled Blue Lias quarry, in the suburbs of north Rugby. Extensively scrubbed over but with limited areas of species-rich calcareous grassland. A Local Nature Reserve managed by Warwickshire Wildlife Trust. Dates of visits: 23.iv.1995, 16.iii.1997, 7.iv.2002, 2.vi.2002, 14.vii.2002, 1.ix.2002, 18.x.2002.
11. Ratley Grange (Edge Hill) Quarry (RG) SP371470. A large Marlstone quarry on the top of Edge Hill, which was being actively worked during the survey period (in a pattern that permitted plentiful ruderal habitat to form), but currently lacking much of its original interest and likely to be developed. Dates of visits: 25.iv.1996, 7.vii.1996, 27.viii.1996, 21.viii.1997, 8.vi.2001, 4.v.2002.
12. Southam Quarry (So) SP421634. A very large series of quarries and spoilheaps, with exposures of White Lias and Blue Lias, still partially worked by RMC for cement and expanding. Very extensive species-rich calcareous grassland and ruderal habitats, scrub and limited wetlands. Dates of visits: 26.v.1998, 11.viii.1999, 23.v.2001, 23.vi.2001, 10.viii.2001, 27.iii.2002, 24.iv.2002, 19.vi.2002, 27.vii.2002, 11.viii.2002.
13. Stockton Cutting (St) SP440649. A disused railway cutting plus adjacent Blue Lias quarries with remains of former works, supporting areas of species-rich calcareous grassland, tall herbs and extensive scrub and secondary woodland. Part of a larger SSSI (Stockton Quarries and Cutting SSSI) and a Local Nature Reserve managed by Warwickshire Wildlife Trust. Dates of visits: 27.vi.1990, 12.vii.1990, 9.vi.1991, 12.v.1996, 11.viii.1996, (25.v.2001), 29.iii.2002, 11.iv.2002, 19.v.2002, 11.viii.2002, 6.x.2002.
14. Ufton Fields SSSI (UF) SP381614 – a 32 ha former White and Blue Lias quarry back-filled to form ridges and furrows plus flatter areas. Now supporting a complex mosaic of species-rich grassland and tall herb, scrub, water bodies, swamp, carr and secondary woodland. Also a Warwickshire County Council Country Park and Warwickshire Wildlife Trust reserve. Dates of visits: 1.v.1990, 23.v.1990, 9.vi.1991, 11.iv.1992, 9.ix.1995, 15.iii.1997, (8.v.2001), 30.vii.2001, 14.viii.2001, 26.iii.2002, 6.iv.2002, 11.v.2002, 23.vi.2002, 18.viii.2002, 15.x.2002.

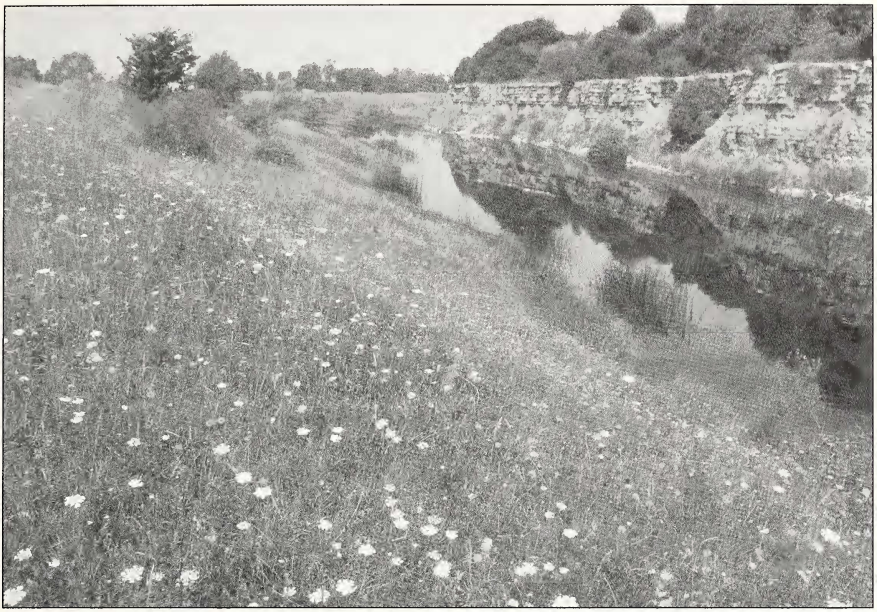

Figure 1. Bishops Bowl.

Figure 2. Nelsons Quarry.

Survey methodology

Surveying took place between 1990 and 2002 with a structured programme of visits in 2001 and 2002 to ensure that most sites received at least five visits extending from March/April to September/October. Some sites received considerably more visits than this due to circumstances (such as the preparation of impact assessments), though by the end of 2002 it had become difficult to extend the site lists much further for bees and wasps. A variety of survey techniques was employed, including visual surveillance of foraging and nesting habitats and careful sweeping of different habitats with a long-handled net, including patches of flowers, sparsely vegetated areas and sunlit foliage. Special attention was given to the flowers that supported the biggest foraging assemblages at particular times of year, which included:

Spring: grey willow *Salix cinerea*, blackthorn *Prunus spinosa*, hawthorns *Crataegus* spp., dandelions *Taraxacum* spp., daisy *Bellis perennis*, coltsfoot *Tussilago farfara*, ground-ivy *Glechoma hederacea* and dead nettles *Lamium* spp.

Early summer: mouse-ear hawkweed *Pilosella officinarum*, hawk's-beards *Crepis* spp., birds-foot trefoils *Lotus* spp., kidney vetch *Anthyllis vulneraria*, vetches *Vicia* spp., hogweed *Heracleum sphondylium*, oxeye daisy *Leucanthemum vulgare* and bramble *Rubus fruticosus* agg.

Mid to late summer: thistles *Cirsium* and *Carduus* spp., ragworts *Senecio* spp., knapweeds *Centaurea* spp., wild parsnip *Pastinaca sativa*, wild carrot *Daucus carota* mignonettes *Reseda* spp., rosebay willowherb *Chamerion angustifolium*, melilots *Melilotus* spp. and hawkweed ox-tongue *Picris hieracioides*.

Late summer–early autumn: perennial sowthistle *Sonchus arvensis*, scentless mayweed *Tripleurospermum inodorum*, hawkbits *Leontodon* spp., angelica *Angelica sylvestris* and late flowers from the previous category.

Persistence and timing were important for producing good lists. The males of *Lasioglossum xanthopus* (Kirby), for example, peak in late September in Warwickshire, a time when many hymenopterists have ceased recording for the year. Other species such as *Andrena praecox* (Scopoli) start foraging so early that they can have peaked by early April in early springs and are difficult to find by the end of this month. Finding species with very narrow foraging habits requires careful surveillance of specific flowers e.g. mignonettes for *Hylaeus signatus* Panzer and willows for *Andrena apicata* Smith, *A. clarkella* (Kirby) and *A. praecox*. For groups containing species that are indistinguishable in the field such as *Sphecodes*, *Lasioglossum*, *Crossocerus* and *Pemphredon*, reasonable-sized samples were obtained for critical checking under a microscope.

Three parameters were then used to assess the quality of the assemblages present:

(i) Species richness. This figure was the total number of bee and wasp species recorded per site during the survey period.

(ii) The presence of rare species. The rarity gradings for Red Data Book and Nationally Scarce species used for assessing this parameter were taken from Falk (1991). However, to allow for the fact that some of these gradings are now known to be misleading, an asterisk has been placed against the obviously mis-graded species in Appendix 2 and a bracketed re-grade suggestion that is more realistic given afterwards. Regional scarcity was assessed using information in the available national atlases published by the Bee, Wasp and Ant Recording Society – 'BWARS' (Edwards, 1997, 1998; Edwards & Telfer, 2001, 2002); also personal data and other literature or correspondence to hand. A rarity score (RS) was evaluated for each site by assigning points to the various rarity

gradings as follows: 100 points to Red Data Book species, 50 points to Nationally Scarce species and 20 points to Regionally Scarce species (following Ball, 1986). The rarity score was also divided by the total number of species at a site to produce a Species Quality Index (SQI) which is stated to even out variable recording coverage across multiple sites. These calculations were made for each of the fourteen study sites (plus sites 2 and 3 combined), following adjustment for obvious misgradings.

(iii) The quality of certain habitat-associated assemblages. A variety of habitat-linked insect assemblages can be used to compare site quality within certain defined parameters. At the sites studied here, these included assemblages associated with open calcareous habitats, shaded calcareous habitats, calcareous wetlands and general wetlands. The first was the main one relevant to the bees and wasps and such species are flagged as calcicoles (Calc) in Table 1 and Appendix 2. A single wetland specific (Wetl) bee was also present at one site, but no bee or wasp species recorded were specialists of shaded calcareous habitats or calcareous wetlands (categories that are important for flies and some other groups). Across the insect fauna as a whole, an interesting assemblage can develop in association with snails at calcareous sites, so a category for snail-associated species was used (Sn), many of which also fall into the calcicole category. These are mostly predatory and parasitic flies and beetles, but include a small number of bees that nest in empty snail shells. The number of aerial nesters at each site i.e. those species nesting in dead wood, hollow stems or amongst foliage (e.g. *Dolichovespula* wasps), was also used as a further parameter specific to bees and wasps. The assignment of species to the calcicole category was based on information in national atlases, other literature and personal data. However, it should be noted that some species that act as calcicoles in Warwickshire, fail to do so in other parts of Britain. This includes *Andrena flavipes* Panzer, *Odynerus melanocephalus* (Gmelin in L.), *Pseudospinolia neglecta* (Schuckard), *Priocnemis parvula* Dahlbom, *Sphecodes ferruginatus* von Hagens and *S. hyalinatus* von Hagens. For *Sphecodes hyalinatus* it stems from the fact that the main Warwickshire host is the calcicolous *Lasioglossum fulvicorne* (Kirby) rather than the acidophilous *L. fratellum* (Pérez) which acts as the main host in many other parts of Britain.

Results

Species richness

Good samples of aculeates were obtained from all fourteen study sites, to the extent that it started to prove difficult to extend the site lists further by the end of the survey period. The data were used to evaluate the quality of the assemblages present at each of the sites (plus sites 2 and 3 combined). The various scores that underpin this evaluation are presented in Table 1. Brief status notes on the scarce species are given in Appendix 1, together with a full species list for each site in Appendix 2.

186 species of bee and wasp (excluding *Apis mellifera* L.) were recorded with certainty from the fourteen sites. The Bishops Bowl–Bishops Hill Complex produced the longest list, of 128 species. Within the West Midlands Region (*sensu* Herefordshire, Worcestershire, Warwickshire, Staffordshire Shropshire and the former West Midlands County), this is only surpassed by Highgate Common, Staffordshire which has recently produced a list of 130 species (S. Falk and

M. Archer, combined data). Southam Quarry produced a list of 112 species. None of the other sites exceeded 100, and the poorest (Lighthorne Quarry) only produced 51 species.

The presence of rare and scarce species

Some very significant records were obtained, including several new county records, substantial national range extensions and numerous records for Red Data Book, Nationally Scarce and Regionally Scarce species. All sites produced records of rare or scarce species, though the number of these, and the SQI value they produced, varied greatly (see Table 1), though the figures were loosely correlated with species richness.

Southam Quarry and the Bishops Bowl–Bishops Hill Complex supported particularly important assemblages of scarcer bees and wasps (24 and 27 species, respectively). Their rarity scores of 1010 and 970, respectively, are probably the highest values for any bee and wasp assemblages in Vice-county Warwickshire and compare well, for example, with some of the better heathlands in the West Midlands Region. The scores were considerably higher than that recently obtained for Sutton Park National Nature Reserve (470) though some way short of that for Highgate Common (1800). These two sites collectively produced records of four rare or scarce species unknown from any other sites in Warwickshire at the time of the survey: *Andrena fulvago* (Christ), *A. proxima* (Kirby), *Hylaeus pectoralis* Forster and *Osmia aurulenta* (Panzer). They also supported important populations of *Bombus ruderatus* (Fab.), *Bombus humilis* Illiger and *Nomada ferruginata* (see Appendix 1). The poorest site for scarce species was Newbold Quarry, with only a single Regionally Scarce species. But even relatively impoverished sites have the ability to support surprisingly rare species. Lighthorne Quarry, the smallest and least rich site, with only six scarce species, still produced a record of the RDB1 *N. ferruginata*. Napton Quarry produced the second highest SQI through the presence of *N. ferruginata*, six Nationally Scarce species and nine Regionally Scarce species within its fauna of only 70 species. But given that the site was clearly nowhere near as rich as the Bishops Bowl–Bishops Hill Complex or Southam Quarry, and had a much lower rarity score, this reveals the danger in placing too much emphasis on SQIs, an evaluation system that is often used unquestioningly in site evaluation and one that can obscure substantial real differences in site quality.

In total, nine species were unknown in Warwickshire from any other sites except those considered here at the time of the survey. In addition to the four listed above, these were *Arachnospila minutula* (Dahlbom), *Caliadurgus fasciatellus* (Spinola), *Lasioglossum xanthopus* (Kirby), *Sphecodes niger* von Hagens and *S. rubicundus* von Hagens (Appendix 1). The records of *H. pectoralis* and *O. aurulenta* are still the only ones the author is aware of in the West Midlands region and represent considerable extensions to their known national ranges. *Andrena proxima* has been discovered at Napton Quarry since the survey finished, but this site and Bishops Bowl are still the only two locations known within the region.

The quality of certain habitat-linked assemblages

Twenty-one calcicoles, 62 aerial nesters (excluding cleptoparasites), three snail-users and one wetland specialist were recorded. The numbers of these found at each site are summarised in Table 1. For calcicoles, Southam Quarry and the Bishops Bowl–Bishops Hill Complex produced a substantially higher score than the other

Table 1. Hymenoptera Quality scores for 14 calcareous localities in Warwickshire, 1990–2002

	Avon Hill Quarry (AH)	Bishops Bowl (BB)	Bishops Hill (BH)	Bishops Bowl + Bishops Hill (BB + BH)	Cross Hands Quarry (CH)	Gypsy Hall (Wilmcote) Quarry (GH)	Harbury Spoilbank (HS)	Lightthorne Quarry (LQ)	Napton Quarry (Na)	Nelsons Quarry (Nel)	Newbold Quarry LNR (New)	Ratley Grange (Edge Hill) Quarry (RG)	Southam Quarry (So)	Stockton Cutting (St)	Ufton Fields SSSI (UF)
# spp	89	90	103	128	71	59	53	51	70	64	65	59	112	68	81
RDB	0	2	0	2	0	0	0	1	1	1	0	0	1	0	0
N	5	6	7	11	7	4	3	1	6	2	0	2	13	7	7
R	8	5	10	11	4	3	4	4	9	7	1	5	13	6	3
RS	410	600	550	970	430	260	230	230	580	340	20	200	1010	470	410
SQI	4.6	6.7	5.3	7.6	6.1	4.4	4.3	4.5	8.3	5.3	0.3	3.4	9.0	6.9	5.0
Calc	8	12	11	15	5	7	7	6	8	7	2	4	13	10	9
Sn	2	2	3	3	2	1	2	2	0	2	0	0	3	2	1
Wetl	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
AN	23	23	22	35	14	5	9	9	7	10	17	8	32	19	23

Values denote the total number of bees and wasp species (# spp), numbers of Red Data Book (RDB), Nationally Scarce (N) and Regionally Scarce (R) species, the Rarity Score (RS) and Species Quality Index (SQI), and the number of calcicolous (Calc), snail-associated (Sn), wetland (Wetl) and aerial nesting (AN) species. Rarity scores were adjusted for obvious misgradings of species. Abbreviated site names are listed in full in the section describing Survey Sites.

sites (15 and 13 calcicoles, respectively), reflecting the extent and quality of the open calcareous habitats present. This compares to only two such species at Newbold Quarry. These sites also supported a much higher number of aerial nesters (35 and 33 such species, respectively) compared to just five such species at Gypsy Hall Quarry. Just these two parameters considered alone can suffice to reflect the quality of a calcareous site as they are functions of site size, habitat quality and habitat diversity, and a simultaneous high score in both parameters reflects all three attributes. Bishops Bowl produced the only record of a wetland aculeate, *Hylaeus pectoralis*, reflecting the presence of extensive reed beds. The numbers of calcicoles and aerial nesters were loosely correlated with species richness.

Discussion

Factors influencing species richness

(i) **The extent of floristically diverse habitat**. The Bishops Bowl–Bishops Hill Complex and Southam Quarry supported the largest expanses of floristically-rich limestone grassland and early successional habitat, with very extensive stands of many key forage plants such as spring-blossoming shrubs, birds-foot trefoils, kidney vetch, various umbellifers, thistles, ragworts, knapweeds, oxeye daisy and scentless mayweed. Species such as *Bombus ruderatus*, *B. humilis* and *Osmia aurulenta* appear to specifically require large areas of flower-rich habitat and depend heavily on plants like birds-foot trefoils. The poorest sites (those with under 70 species recorded) were either characterised by relatively small areas of flower-rich habitat (usually much reduced by scrub encroachment or excessive disturbance) or by a lack of floristic diversity or lack of certain key forage plants within the open habitats that were present. The latter occurred at the three sites featuring Ironstone (only mildly calcareous compared with Lias deposits and lacking many key calcicoles); also at sites where the ground conditions were too xeric for a rich plant community. Blue Lias clay for example can often hold very little water in a dry summer, and in the driest areas it can take several decades to develop a reasonable vegetation cover which may only contain the most drought tolerant species such as dog-rose *Rosa canina* agg., dwarf thistle *Cirsium acaule* and autumn gentian *Gentianella amarella*.

(ii) **The quality of habitat mosaics and adjacent habitats**. Even where sufficiently large areas of flower-rich, calcareous habitats were present, the variety of other habitats and successional stages in and around a quarry was highly influential on richness. Woodland, scrub, and tall herbs can provide important foraging habitats and provide nest sites for a good variety of aerial nesters. Habitats close to a quarry system such as flowery road verges, fields margins, hedges, fallow fields, disused railways and canal banks, even gardens can also boost the aculeate diversity of a quarry, and often support large stands of critical forage plants (especially thistles, hogweed and scentless mayweed) that may be scarce or absent within the quarry itself. It is important to be aware of the landscape around a quarry site when trying to understand the factors influencing the bee and wasp fauna, and to be aware of the likelihood that in some aculeate species local populations are operating at a landscape level across a cluster of suitable sites.

(iii) **Geology and site history**. It is thought that geology can influence the precise composition of bee and wasp assemblages, though it is difficult to separate the affects of geology from the other variables at play, particularly the history of a

site and the pattern of operations associated with its active phase. The large Blue Lias quarries studied appear to have the greatest potential for bees and wasps, possibly because of the piecemeal pattern of operations usually associated with the cement industry. This tends to produce large spoilheaps and other areas that are allowed to re-vegetate naturally at different times and rates, and to create new quarries adjacent to older, abandoned ones, resulting in complex habitat mosaics. Clay-rich overburden was often mounded up and can produce different conditions to pure Lias deposits. The inability of ironstone quarries to support certain key calcicolous plants has already been mentioned. Uneven quarry floors can result in a complex mosaic of wetland conditions ranging from permanent deep water through to seasonally-flooded inundation marsh and damp ditches and hollows. This can promote the abundance of valuable forage plants such as grey willow, angelica and marsh thistle *Cirsium palustre*, which prefer damp soils. As a rule, longer-abandoned sites tended to exhibit more advanced levels of succession such as scrub encroachment or the development of coarse grassland and have often lost much of their early successional habitats and the aculeates that require these. Rabbit activity and informal human disturbance can sometimes slow down the rate of succession or completely arrest it locally.

(iv) **Topography and altitude**. A number of the sites were located on fairly high ridges or hills e.g. Cross Hands Quarry, Napton Quarry and Ratley Grange Quarry. These tended to be more exposed to prevailing winds and on a given day (especially a windy one) were often somewhat cooler than nearby sites in less exposed locations. This appeared to reduce species diversity. Newbold Quarry suffered from the fact that much of its species-rich limestone grassland was on north-facing slopes or overshadowed by wooded slopes to the south. This reduced the extent of warm habitat available for thermophilic insects such as bees and wasps.

Factors influencing the number of rare and scarce species and key habitat-linked assemblages

These appear to be much the same as those influencing species richness, and the presence of scarcer species seemed strongly influenced by species richness. Larger sites with extensive, flowery calcareous habitat within a larger habitat mosaic had greater capacity for supporting the key forage plants and ideal nesting sites required by scarcer species and calcicoles. But for some individual rare species and calcicoles, it may have been the abundance of just a small number of flower species that supported their presence. *Andrena proxima* owed its occurrence at Bishops Bowl to a large patch of ground-elder *Aegopodium podagraria*. At Southam Quarry, *Bombus humilis*, *B. ruderatus* and *Osmia aurulenta* were heavily reliant on the very extensive birds-foot trefoils and kidney vetch there. The rare cleptoparasite *Nomada ferruginata* was indirectly dependent on the willows that feed its sole host *Andrena praecox*. *Hylaeus signatus* was entirely dependent on wild mignonette *Reseda lutea* and weld *R. luteola*.

Evidence of losses and gains in the bee and wasp fauna

The low level of insect recording at most of the study sites prior to the 1980s hinders our knowledge of losses. The only certain loss is that of *Bombus sylvarum* (L.), which was present at Ufton Fields as late as 1965 (the last record for

Warwickshire). However, extensive infilling and landscaping of Cross Hands and Ratley Grange Quarries have almost certainly resulted in losses here over recent years, including half of the known Warwickshire sites for *Lasioglossum xanthopus*. Excessive scrub encroachment has probably reduced the diversity of at least four further sites (see Vegetation succession below). Rather more evidence is available for recent gains, and this mostly relates to species known to be expanding their ranges nationally. These include *Andrena flavipes*, *Crossocerus distinguendus* (A. Morawitz), *Dolichovespula media* (Retzius), *D. saxonica* (Fab.), *Ectemnius rubicola* (Dufour & Perris), *Lasioglossum malachurum*, *Microdynerus exilis* and *Philanthus triangulum* (Fab.). and possibly also *Didineis lunicornis* (Fab.), *Andrena proxima*, *Hylaeus cornutus* Curtis, *Hylaeus pectoralis* and *Sphecodes niger*. Climatic factors appear to underlie these expansions, and the sites considered here appear to represent important stepping stones for such expanding species (the intervening countryside providing few opportunities). These records indicate the dispersal abilities of such species, which is usually poorly documented.

The relative national importance of the study sites for bees and wasps

The level of species richness and number of rare and scarce species encountered across the fourteen study sites was comparable to that associated with lowland heathland in the West Midlands (S. Falk data). In the West Midlands Region, any modern list exceeding 100 species can be regarded as extremely good, though heathland sites in counties such as Surrey and chalk heath sites in the East Anglian Brecks by comparison still occasionally produce lists of 200 or more species (S. Falk, D. Baldock & J. Field data). Rather surprisingly, the best calcareous sites on the East Sussex downs, including a number of National Nature Reserves and SSSIs, do not appear to be much richer than the best sites covered here (S. Falk data). This may reflect the less complex topography and habitat mosaics associated with many ancient downland sites compared with large quarries. Based on such comparisons, sites such as the Bishops Bowl–Bishops Hill Complex and Southam Quarry ought to be viewed as nationally significant. Southam Quarry is also noteworthy in that it produced records for 14 *Bombus* species (9 non-parasitic ones and 5 'cuckoo' species). It appears to be the richest bumblebee site in the British Midlands today.

General factors affecting the bee and wasp fauna at these sites

(i) Vegetation succession

The intensity of operations at many quarries during their peak of productivity can limit their entomological and botanical interest. Diversity increases as soon as quarries are partially or completely abandoned and flower-rich vegetation starts to establish. The optimal condition for bees and wasps will tend to occur once a range of floristically diverse conditions, representing a variety of successional stages, has developed. This may take 10–30 years after abandonment, depending on the size of a site and factors such as rabbit levels, hydrology, soil chemistry, and physical disturbance. Flowery early successional stages with plants such as oxeye daisy, hawk's-beards, birds-foot trefoils and kidney vetch are vital for many aculeates, but areas of scrub, bramble and tall herb can also provide valuable foraging habitat and a source of nesting sites for aerial nesters. But, without further management or disturbance, excessive encroachment of such habitats or floristically poor grassland

such as dense wood false-brome *Brachypodium sylvaticum* can swamp out valuable early successional stages, reducing the diversity of conditions and, in consequence, reduce the variety of bees and wasps. A number of the study sites have deteriorated in the past through the effects of succession, notably Ufton Fields SSSI, Stockton Quarries and Cutting SSSI (containing Stockton Cutting and Nelsons Quarry), Harbury Railway Cutting SSSI and Newbold Quarry LNR. SSSI notification made little difference. Most of these sites are now subject to active scrub control, but have lost a number of calcicolous insects as a result of their recent history, including butterflies such as the small blue *Cupido minimus* (Fuessley). It is presumed certain bees and wasps have been lost too, including some of the species currently confined to the Bishops Bowl–Bishops Hill Complex and Southam Quarry, which currently support the conditions once associated with these other sites.

(ii) Quarry infilling and landscaping

Two sites have been subject to partial infilling and landscaping, Cross Hands Quarry and Ratley Grange Quarry. Currently, it is likely that most of the scarcer bees and wasps recorded there during this study have been lost. The re-establishment of flower-rich vegetation may draw some of these species back, though it awaits to be seen whether the restored sites will regain high quality habitat. However, there is proven potential for land-filled and restored quarries and spoilheaps to regain high entomological value within a decade or two if capped with low fertility sub-soil sourced from other parts of the quarries and allowed to re-vegetate naturally over a sufficiently large area. Bishops Hill, for example, was subject to major re-profiling in the late 1980s, which was viewed as highly damaging to the ecology at the time, but the new ground had already acquired floristically diverse conditions and strong populations of many scarce bees and wasps by the mid-1990s. The most valuable part of Southam Quarry today is a re-vegetated mound of clay that was bare only a couple of decades ago. Where landscaping for nature conservation is taking place, it is essential that the introduction of top soil is avoided and that natural plant regeneration directly from the indigenous seed bank is encouraged. It is also important to produce plenty of south-facing slopes, including banks and some vertical faces.

(iii) Development

During the time of writing, planning applications for development proposals that could substantially impact on site quality had been submitted for Bishops Hill, Bishops Bowl, Ratley Grange Quarry and the lower part of Napton Quarry. This is not surprising given that all the sites covered here fall within a developer's concept of 'brown-field' land which is still unquestioningly viewed as a more acceptable location for development than 'green-field' land (even though the latter is predominantly ecologically impoverished farmland in Warwickshire). Some of the impact assessments associated with these proposals have been very deficient, either due to poor expertise on the part of the ecological consultants working for the applicants, or a lack of sufficient resources or time for bona-fide ecologists to carry out sufficiently detailed surveys, data searches and impact analysis. The development of Individual Species Impact Assessments by the author (Falk, 1998) was a direct response to a deficient impact assessment at one of the sites covered by this paper. Several of the abandoned quarries in the suburbs of Rugby have become surrounded by residential or industrial development over the past 20–40 years, which has left a legacy of rather

isolated quarries with little subsidiary habitat. The agricultural land surrounding other sites has become much more intensively farmed in the latter part of the twentieth century, reducing the amount of subsidiary foraging habitat and possibly exposing quarries to the effects of pesticide drift.

(iv) Excessive disturbance

This is more of a perceived threat than a real one, and nearly all of the study sites would benefit from higher levels of periodic, piecemeal disturbance, especially where this keeps the encroachment of scrub and wood false-brome in check. Avon Hill Quarry currently permits regular meetings of four-wheeled drive vehicles, which follow set routes through an interesting configuration of humps and hollows. Some parts of the site receive intense pressure, but overall the effect is beneficial, resulting in a complex array of early successional stages with good patches of birds-foot trefoils, mouse-ear hawkweed, melilots and clovers. Even where examples of large-scale disturbance have taken place, calcareous substrates have generally shown a remarkable ability to regain floristically diverse conditions with plentiful calcicoles once disturbance ceases.

(v) Site designation

Four of the fourteen sites constitute biological SSSIs: Harbury Spoilbank, Stockton Cutting and the nearby Nelsons Quarry (forming parts of one larger SSSI) and Ufton Fields. This affords legal protection from damaging operations, though, as noted above, it has not protected them from the insidious effects of vegetation succession in the past. Their aculeate faunas are now considerably less diverse then those of the Bishops Hill–Bishop Bowl Complex and Southam Quarry, with fewer rare species. Newbold Quarry is a Local Nature Reserve and Ufton Fields is a Warwickshire County Council Country Park. These designations afford substantial protection as they are generally applied to land that is considered out of bounds to development proposals and under sympathetic ownership. Few of the remaining sites have yet to be formally designated as Second-tier Wildlife Sites (locally termed 'SINCS' – Sites of Importance for Nature Conservation), though most are flagged as 'provisional SINCs' or 'Ecosites' to alert local planning authorities of the need to treat planning proposals affecting them with appropriate vigilance. The Bishops Bowl–Bishops Hill Complex was designated as a provisional SINC during the preparation of this paper, largely on the basis of its entomological value and it is expected that others will follow. Entomological site data can be a powerful tool for designation where it is sufficiently detailed, comparative and interpreted.

(vi) Site management and monitoring

Three of the four SSSIs have been managed by Warwickshire Wildlife Trust (WWT) over a number of decades, with financial support through English Nature's Reserves Enhancement Scheme. Newbold Quarry LNR is also a WWT Reserve. Ironically, it is these four sites that experienced the greatest past losses of flower-rich habitat through scrub encroachment. The substantial resources required for effective scrub control have been badly under-estimated in the past, and the ecology of many of the scarcer insects was poorly appreciated, resulting in a gradual loss of the extensive early successional stages required by many such species. But now that these issues are more fully appreciated, substantial efforts are being made to restore these

sites to their former value and WWT is better placed to achieve this than any other organisation in the county. However, sites including the Bishops Bowl–Bishops Hill Complex, Avon Hill Quarry, Lighthorne Quarry and Gypsy Hall are largely unmanaged and reliant upon rabbit grazing, physical disturbance unrelated to nature conservation and soil characteristics to keep succession in check. As such they must be considered vulnerable.

(vii) Local Biodiversity Action Plans (LBAPs)

The bee and wasp fauna of Warwickshire's calcareous sites is catered for in three habitat action plans in the Warwickshire, Coventry and Solihull LBAP: Quarries and Gravel Pits, Lowland Calcareous Grassland and Disused Industrial and Railway Land. These contain a variety of targets for habitat management, restoration, creation and designation. Species action plans have also been produced for *Nomada ferruginata* and jointly for *Bombus humilis* and *B. ruderatus*, three species featured in the National Biodiversity Action Plan (Anon, 1999). The various habitat and species action plans for Warwickshire can be viewed on the web at: www.warwickshire.gov.uk/biodiversity.

Conclusions

Warwickshire's calcareous quarries and spoilheaps contribute substantially to the biodiversity of bees and wasps in Britain, by allowing many species new opportunities for range expansion, by supporting a good number of scarce species, and by producing some very valuable calcicolous assemblages. The level of interest may be considerably greater than the ancient calcareous grasslands that preceded their existence (which are likely to have been less physically diverse). But threats to these assemblages are manifold and do not necessarily cease following protective designation, especially if insufficient management is taking place. Assessing the quality of sites should ideally examine the quality of habitat-associated assemblages in addition to noting species richness and the presence of scarcer species, but great caution is urged with the use of SQIs. The Southam Quarry and Bishops Bowl–Bishops Hill Complex both require notification as SSSIs to help preserve their nationally important but vulnerable assemblages.

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Appendix 1. Notes on some of the scarcer species

Andrena bucephala Stephens and *Nomada hirtipes* Pérez – *A. bucephala* shows strong calcicolous tendencies in Warwickshire and the dozen or so sites fall into three categories: re-vegetated quarries and spoilheaps, railway cuttings, and south-facing Cotswoldian hillsides with patches of scrub. Foraging mostly occurs on hawthorn and field maple *Acer campestre* during May, and males can form conspicuous swarms around such blossoms. The communal nests (several females sharing a common nest entrance) are often associated with rabbit burrows within a scrub-grassland mosaic. Five of the strongest *A. bucephala* colonies support *N. hirtipes*, the nomad bees often revealing the precise location of the host's nest. Both species are very rare abroad (G. Else, personal communication), making all British colonies highly significant.

Andrena dorsata (Kirby) – noteworthy for its rarity in Warwickshire – it is a frequent species in many parts of southern Britain, preferring heathland and coastal districts. The Avon Hill record (a single male on grey willow catkins) is one of only two modern ones for the county and its presence here may have been influenced by flowering gorse thickets (a major foraging habitat for first generation females at many sites) on nearby hills.

Andrena flavipes – almost certainly a recent colonist in Warwickshire, where first recorded in 1999 on agricultural land. All but two of the subsequent records fall within the sites covered here and suggest that calcareous quarries provide the most ideal habitat for it in Warwickshire.

Andrena fulvago – the Southam record (23 May 2001) is the only modern one for Warwickshire (1950s H.W. Daltry material from 'Rugby' exists at Coventry Museum). Only a single female was encountered, close to a patch of *Crepis*, a likely forage plant.

Andrena praecox – not considered especially scarce nationally. However, the Warwickshire populations are unusual in showing strong calcicolous tendency, preferring to nest in bare or sparsely-vegetated Lias clay at sites with plentiful willows. At the sites considered here, foraging was observed on grey willow, goat willow *Salix caprea* and (at the end of its flight period) white willow *S. alba*. The other two willow-requiring mining bees, *A apicata* Smith and *A. clarkella* (Kirby) lack strong calcicolous tendencies, indeed *A. clarkella* favours sandy, acidic sites in districts away from limestone and the populations encountered during this survey were very weak.

Andrena proxima – a strong population was discovered at Bishops Bowl, representing a considerable extension to its known range in Britain. Males were numerous on 7 May 2001 swarming over paths and visiting daisy flowers. Females were recorded on 11 June 2001 and 8 June 2002 mainly foraging on a large patch of ground elder, and hogweed to a lesser extent. It is suspected that this is another species increasing in range and frequency within southern Britain (S. Falk data) and it has been recorded at Napton Quarry in 2005 subsequent to the survey.

Arachnospila minutula – Bishops Hill and Southam Quarry support the only populations known in Warwickshire.

Bombus humilis – the Southam Quarry population is the stronger of the two modern ones known in Warwickshire (the other population may already have been lost since 1995). At Southam, a queen was recorded foraging on *Lotus* spp. on the relatively late date of 23 May 2001. Workers were also observed visiting *Lotus* and red bartsia *Odontites verna* in July and August. Compared with the closely-related *B. pascuorum* (Scopoli), *B. humilis* seems to have a much shorter foraging season involving fewer forage species.

Bombus ruderatus – at Southam, a queen was found foraging on *Anthyllis* flowers on 23 May 2001 and presumed workers (which are very difficult to distinguish from those of *B. hortorum* (L.) but often include fully melanic individuals) were foraging almost exclusively on *Lotus* until August. Like *B. humilis*, a relatively short foraging period and limited foraging scope were noted, compared to the closely-related *B. hortorum*. This BAP Priority Species seems to be exhibiting a major expansion in south Warwickshire at the time of writing (S. Falk data), which is rather surprising given that it has been traditionally regarded as one of the most seriously declined British bumblebees.

Caliadurgus fasciatellus – the closely approximated Southam Quarry and Stockton Cutting support the only populations known in Warwickshire, which are associated with sparsely-vegetated Blue Lias clay.

Crossocerus distinguendus – seemingly another recent colonist, first discovered in Warwickshire in 1998, since when it has been found at six sites of rather different character including one of the sites covered here, Cross Hands Quarry.

Didineis lunicornis – only a single record from the present study (Ufton Fields), plus a further record for Newbold Quarry (R. Wright, personal communication), though many of the sites appear to provide ideal habitat (sparsely-vegetated clay with desiccation cracks). Its other four Warwickshire sites include sheep or rabbit grazed hillsides and railway cuttings.

Dipogon variegatus (L.) – the Avon Hill record is only the second for Warwickshire. It was first recorded in July 1998 from a post-industrial site in Coventry, which has since been developed.

Ectemnius sexcinctus (Fab.) – the Cross Hands and Southam records are the third and fourth for the county.

Hylaeus cornutus – the Southam record is only the second for Warwickshire, and the locality of the previous record (a post-industrial site in Coventry) has now been developed. At both sites it was recorded on wild carrot flowers.

Hylaeus pectoralis – a most unexpected record representing a substantial extension to its known range in Britain. The site involved, Bishop Bowl, supports the largest stands of *Phragmites* of all the sites surveyed. The wasp nests in dead stems of reeds and the old galls of *Lipara* flies on reeds.

Hylaeus signatus – the three sites covered here repeat a pattern seen elsewhere in the county of a species with an almost complete reliance on 'brownfield' land, in association with *Reseda* spp. However, the colonies at calcareous quarries are relatively weak compared with those associated with post-industrial sites in the Coventry region during the 1990s, possibly because of the greater frequency of *Reseda*-rich habitat in the Coventry area during the 1990s (much of which has now been developed).

Lasioglossum malachurum – seemingly another recent colonist in Warwickshire where it was first recorded in 1999. Seven of its ten Warwickshire sites are calcareous quarries and females forage on a wide variety of flowers, but especially composites such as daisy, hawk-beards and oxe-eye daisy. Observed nesting colonies have been associated with hard clay ground.

Lasioglossum xanthopus – Warwickshire records are currently confined to the four calcareous quarries covered in this paper. Females have been observed foraging heavily from ragworts and kidney vetch in May and June and nesting in vertical banks. Males have been found on perennial sowthistle flowers in late September. No evidence of its scarce cleptoparasite *Sphecodes spinulosus* von Hagens could be found, though both species occur in a disused railway cutting just over the Oxfordshire border (C. O'Toole, pers. comm.). Populations at two of its four sites (Cross Hands and Ratley Grange Quarries) have almost certainly been lost since the records were made through recent landfilling and restoration operations.

Microdynerus exilis (Herrich-Schäffer) – the Southam record is the second for Warwickshire where it was first recorded in August 1998 (a post-industrial site in Coventry that has since been developed).

Nomada ferruginata – the Napton population, which was first discovered in April 1996, is a strong one with good numbers observed around a nesting colony of the host *Andrena praecox* that forages on the plentiful grey willow here. The Bishops Bowl and Lighthorne Heath records relate to singletons, and the presence of only a few grey willow bushes at Lighthorne suggests this site does not support a secure population of the host. National data (Edwards & Telfer, 2002) suggests *N. ferruginata* may be currently expanding in southern Britain, and does not support its continued grading as an RDB1 species.

Odynerus melanocephalus – only two further Warwickshire sites are known beyond the nine covered by this paper, and all sites are characterised by the presence of bare or sparsely vegetated clay slopes with plentiful black medick *Medicago lupulina* – the source of its prey, the larvae of *Hypera* weevils (pers. observ.). The short-funnelled nests have been observed on a few such slopes, and contrast strongly with the long-funnelled nests of *O. spinipes* that tend to occur in vertical sand or clay faces (often the sandy overburden at the top of a limestone quarry face). The majority of Warwickshire records for the *Odynerus* cleptoparasite *Pseudospinolia neglecta* are associated with *O. melanocephalus*, though a strong population was formerly associated with *O. spinipes* at Ufton.

Osmia bicolor – this is one of our most strongly calcicolous bees, with only two other known Warwickshire sites beyond the twelve shown here. Females have mainly

been observed foraging from birds-foot trefoils and kidney vetch, though visits to ground ivy, hawthorn, crab apple *Malus sylvestris*, willows, dandelions, brambles, violets *Viola* spp. and cowslip *Primula veris* have also been noted and males will visit composites like mouse-ear hawkweed and hawks-beards. Another strongly calcicolous megachiline bee *Hoplitis spinulosa* (Kirby) occurs alongside *O. bicolor* at many of its sites but forages almost exclusively on composites. The suitability of sites probably depends on the combination of plentiful forage plants combined with an abundance of empty snail shells in warm, sheltered locations fully exposed to the sun (the nesting site).

Osmia aurulenta – the Bishops Hill and Southam Quarry populations are remarkable for their isolated location in the centre of England far from any other known colonies. This is typically a species of calcareous coastal dunes with a more limited presence inland, mainly on chalk grassland. Foraging has only been observed from birds-foot trefoils and kidney vetch and it seems to require large quantities of such flowers, combined with an abundance of empty snail shells in open locations fully exposed to the sun for nesting.

Philanthus triangulum – singletons recorded from two sites. A recent colonist in Warwickshire, first recorded in 1995, with about a dozen records since. The sites studied here do not appear to be sandy enough to support strong colonies.

Priocnemis agilis (Schuckard) – Bishops Bowl is one of six Warwickshire sites, all of which are calcareous grasslands including semi-improved calcarous pasture.

Priocnemis parvula Dahlbom – strongly associated with heathland and other sandy habitats over much of its range. Its presence at six of the calcareous sites studied here is noteworthy, though its presence at several non-calcareous sites locally has kept it off the calcicole list.

Psenulus schencki (Tournier) – the Ufton record is the second for Warwickshire, where it was first recorded in 1999.

Sphecodes niger – the Nelsons Quarry record is the first for Warwickshire and coincides with a particularly strong colony of the host *Lasioglossum morio* (Fab.). Another species expanding nationally (S. Falk data, M. Edwards, pers. comm.).

Sphecodes rubicundus – the Napton Quarry and Bishops Bowl records were the only ones for Warwickshire at the time of the study (two more sites have subsequently been discovered) and coincide with strong populations of its main host, *Andrena labialis* (Kirby), which requires plentiful legume flowers.

Appendix 2. A list of all bees and wasps recorded at the 14 sites between 1990 and 2002.

The Status column lists various Quality Indicators. This includes species graded as Nationally Threatened (RDB1, 2, 3 & K), Nationally Scarce (N), Regionally Scarce 'sensu Vice-county Warwickshire' (R), calcicolous (Calc) and wetland-associated (Wetl). An asterisk after a grade indicates a misleading national grading and is followed by a bracketed value indicating a more realistic grading. A species name followed by an asterisk relates to species unknown from any other site in Warwickshire beyond those shown. Abbreviated site names are listed in the section on Survey Sites.

ACULEATE HYMENOPTERA	Rarity/ Quality Status	AH	BB	BH	BB+ BH	CH	GH	HS	LQ	Na	Nel	New	RG	So	St	UF
Chrysididae																
Chrysis angustula Schenck				/	/							/				
Chrysis impressa Schenck			/		/			/								/
Omalus puncticollis (Mocsáry)	N			/	/										/	
Pseudomalus auratus (L.)		/										/				
Pseudospinolia neglecta (Schuckard)	R, Calc	/								/			/	/		/
Trichrysis cyanea (L.)				/	/	/			/					/		/
Sapygidae																
(*Monosapyga clavicornis* L.)	N															/
Sapyga quinquepunctata (Fab.)		/														
Tiphiidae																
Tiphia minuta Vander Linden	N* (no status)	/	/	/	/	/		/	/	/	/			/		/
Mutillidae																
Myrmosa atra Panzer			/	/	/		/			/				/		/
Pompilidae																
Agenioideus cinctellus (Spinola)	R					/										
Anoplius concinnus (Dahlbom)	R			/	/											
Anoplius nigerrimus (Scopoli)		/	/	/	/		/	/	/			/			/	
Arachnospila anceps (Wesmael)							/			/				/		

Arachnospila minutula (Dahlbom)*	N, Calc			/	/					/				/		
Arachnospila spissa (Schiødte)				/	/		/	/								
Caliadurgus fasciatellus (Spinola)*	R													/	/	
Dipogon subintermedius (Magretti)				/	/											
Dipogon variegatus (L.)	R	/														
Priocnemis agilis (Schuckard)	N, Calc		/		/											
Priocnemis exaltata (Fab.)			/	/	/		/			/				/		/
Priocnemis parvula Dahlbom	R			/	/		/		/	/	/			/		
Priocnemis perturbator (Harris)				/	/		/	/		/	/					
Vespidae																
Ancistrocerus gazella (Panzer)		/		/	/					/				/		
Ancistrocerus nigricornis (Curtis)		/				/										
Ancistrocerus parietinus (L.)														/		
Ancistrocerus parietum (L.)		/	/		/											
Ancistrocerus trifasciatus (Müller)		/	/	/	/										/	
Dolichovespula media (Retzius)	N* (no status)		/	/	/								/			/
Dolichovespula norwegica (Fab.)				/	/											
Dolichovespula saxonica (Fab.)	RDBK* (no status)			/	/								/			/
Dolichovespula sylvestris (Scopoli)		/		/	/	/			/							
Gymnomerus laevipes (Schuckard)	R	/											/	/		
Microdynerus exilis (Herrich-Schäffer)	N													/		
Odynerus melanocephalus (Gmelin in L.)	N, Calc	/	/	/	/	/				/	/		/	/	/	
Odynerus spinipes (L.)	R										/			/		/
Symmorphus bifasciatus (L.)														/		
Symmorphus gracilis (Brullé)		/														
Vespula germanica (Fab.)		/	/	/	/	/	/	/		/	/	/		/	/	/
Vespula rufa (L.)												/				/
Vespula vulgaris (L.)		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

(continued)

Appendix 2. A list of all bees and wasps recorded at the 14 sites between 1990 and 2002.

The Status column lists various Quality Indicators. This includes species graded as Nationally Threatened (RDB1, 2, 3 & K), Nationally Scarce (N), Regionally Scarce 'sensu Vice-county Warwickshire' (R), calcicolous (Calc) and wetland-associated (Wetl). An asterisk after a grade indicates a misleading national grading and is followed by a bracketed value indicating a more realistic grading. A species name followed by an asterisk relates to species unknown from any other site in Warwickshire beyond those shown. Abbreviated site names are listed in the section on Survey Sites.

ACULEATE HYMENOPTERA	Rarity/ Quality Status	AH	BB	BH	BB+ BH	CH	GH	HS	LQ	Na	Nel	New	RG	So	St	UF
Chrysididae																
Chrysis angustula Schenck				/	/							/				
Chrysis inpressa Schenck			/					/								/
Omalus puncticollis (Mocsáry)	N															
Pseudomalus auratus (L.)																
Pseudospinolia neglecta (Schuckard)	R, Calc															
Trichrysis cyanea (L.)				/	/	/			/					/		
Sapygidae																
(*Monosapyga clavicornis* L.)	N															
Sapyga quinquepunctata (Fab.)																
Tiphiidae																
Tiphia minuta Vander Linden	N* (no status)		/	/	/	/		/	/	/	/			/		/
Mutillidae																
Myrmosa atra Panzer			/	/												
Pompilidae																
Agenioideus cinctellus (Spinola)	R															
Anoplius concinnus (Dahlbom)	R															
Anoplius nigerrimus (Scopoli)																
Arachnospila anceps (Wesmael)										/						

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Arachnospila minuta (Dahlbom)*	N, Calc				/					/				/		
Arachnospila spissa (Schiodte)					/		/									
Caliadurgus fasciatellus (Spinola)*	R															
Dipogon subintermedius (Magretti)																
Dipogon variegatus (L.)	R															
Priocnemis agilis (Schuckard)	N, Calc		/		/											
Priocnemis exaltata (Fab.)			/		/		/			/				/		/
Priocnemis parvula Dahlbom	R															
Priocnemis perturbator (Harris)																
Vespidae																
Ancistrocerus gazella (Panzer)		/		/	/					/				/		
Ancistrocerus nigricornis (Curtis)																
Ancistrocerus parietinus (L.)																
Ancistrocerus parietum (L.)																
Ancistrocerus trifasciatus (Müller)			/	/	/										/	
Dolichovespula media (Retzius)	N* (no status)		/	/	/								/			/
Dolichovespula norwegica (Fab.)																
Dolichovespula saxonica (Fab.)	RDBK* (no status)															
Dolichovespula sylvestris (Scopoli)		/		/	/	/			/							
Gymnomerus laevipes (Shuckard)	R	/											/	/		
Microdynerus exilis (Herrich-Schäffer)	N													/		
Odynerus melanocephalus (Gmelin in L.)	N, Calc															
Odynerus spinipes (L.)	R										/			/		/
Symmorphus bifasciatus (L.)														/		
Symmorphus gracilis (Brullé)		/														
Vespula germanica (Fab.)		/								/				/	/	/
Vespula rufa (L.)												/				
Vespula vulgaris (L.)		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

(continued)

Appendix 2. *(continued)*

ACULEATE HYMENOPTERA	Rarity/ Quality Status	AH	BB	BH	BB+ BH	CH	GH	HS	LQ	Na	Nel	New	RG	So	St	UF
Crabonidae																
Argogorytes fargeii (Schuckard)	N									/				/		
Cerceris rybyensis (L.)	R			/	/					/						
Crossocerus annulipes (Lepeletier & Brullé)				/	/					/				/		/
Crossocerus capitosus (Schuckard)		/		/	/	/	/					/		/		/
Crossocerus cetratus (Schuckard)			/		/			/			/			/	/	/
Crossocerus dimidiatus (Fab.)				/	/						/					
Crossocerus distinguendus (Morawitz, A.)	N					/										
Crossocerus elongatulus (Vander Linden)						/						/		/	/	
Crossocerus megacephalus (Rossius)		/						/							/	/
Crossocerus nigritus (Lepeletier & Brullé)		/					/					/			/	/
Crossocerus podagricus (Vander Linden)		/	/	/	/		/	/	/		/	/		/	/	/
Crossocerus pusillus (Lepeletier & Brullé)				/	/									/		
Crossocerus tarsatus (Schuckard)				/	/	/							/			
Didineis lunicornis (Fab.)	N, Calc															/
Diodontus luperus Schuckard	R	/		/	/	/				/			/	/		
Ectemnius cavifrons (Thomson)															/	/
Ectemnius continuus (Fab.)		/	/		/									/		
Ectemnius rubicola (Dufour & Perris)	R							/	/					/	/	
Ectemnius sexcinctus (Fab.)	N					/								/		
Entomognathus brevis (Vander Linden)		/	/	/	/	/					/			/		
Gorytes quadrifasciatus (Fab.)		/		/	/									/		
Harpactus tumidus (Panzer)	R									?				/		
Lindenius albilabris (Fab.)				/	/							/				

Mellinus arvensis (L.)	R													/		
Mimumesa dahlbomi (Wesmael)			/		/											
Nysson dimidiatus Jurine	N									/						
Nysson trimaculatus (Rossius)	N	/														
Oxybelus uniglumis (L.)		/						/		/				/		
Passaloecus corniger Shuckard							/									
Passaloecus gracilis (Curtis)												/				
Passaloecus singularis Dahlbom				/	/	/		/	/		/	/		/	/	/
Pemphredon inornata Say		/	/	/	/			/			/	/		/	/	/
Pemphredon lethifera (Shuckard)		/	/	/	/	/								/		
Pemphredon lugubris (Fab.)												/	/		/	
Pemphredon morio Vander Linden	N														/	
Philanthus triangulum (Fab.)	RDB2* (R)	/		/	/					/						
Psenulus concolor (Dahlbom)		/									/	/	/			
Psenulus pallipes (Panzer)			/		/				/			/		/		
Psenulus schencki (Tournier)	N															/
Rhopalum clavipes (L.)						/			/							/
Rhopalum coarctatum (Scopoli)			/		/							/			/	/
Spilomena beata Blüthgen	R													/		
Spilomena troglodytes (Vander Vinden)			/		/	/								/	/	/
Stigmus solskyi Morawitz											/					/
Tachysphex pompiliformis (Panzer)	R									/						
Trypoxylon attenuatum Smith		/	/	/	/	/				/	/		/	/	/	/
Trypoxylon clavicerum Lepeletier & Serville			/	/	/									/		
Trypoxylon figulus (L.) 's.s.'						/										
Trypoxylon 'figulus s.l.'											/			/		
Apidae																
Andrena apicata Smith	N					/				/						
Andrena bicolor Fab.		/		/	/	/	/		/	/		/	/	/		
Andrena bucephala Stephens	N, Calc						/	/							/	/
Andrena chrysosceles (Kirby)		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

(*continued*)

Appendix 2. *(continued)*

ACULEATE HYMENOPTERA	Rarity/ Quality Status	AH	BB	BH	BB+ BH	CH	GH	HS	LQ	Na	Nel	New	RG	So	St	UF
Crabonidae																
Argogorytes fargeii (Schuckard)	N															
Cerceris rybyensis (L.)	R															
Crossocerus annulipes (Lepeletier & Brullé)				/	/					/				/		
Crossocerus capitosus (Schuckard)																
Crossocerus cetratus (Schuckard)																
Crossocerus dimidiatus (Fab.)																
Crossocerus distinguendus (Morawitz, A.)	N															
Crossocerus elongatulus (Vander Linden)																
Crossocerus megacephalus (Rossius)																
Crossocerus nigritus (Lepeletier & Brullé)																
Crossocerus podagricus (Vander Linden)																
Crossocerus pusillus (Lepeletier & Brullé)																
Crossocerus tarsatus (Schuckard)																
Didineis lunicornis (Fab.)	N, Calc															
Diodontus luperus Schuckard	R															
Ectemnius cavifrons (Thomson)																
Ectemnius continuus (Fab.)																
Ectemnius rubicola (Dufour & Perris)	R															
Ectemnius sexcinctus (Fab.)	N															
Entomognathus brevis (Vander Linden)																
Gorytes quadrifasciatus (Fab.)																
Harpactus tumidus (Panzer)	R															
Lindenius albilabris (Fab.)																

Mellinus arvensis (L.)	R													/		
Mimumesa dahlbomi (Wesmael)																
Nysson dimidiatus Jurine	N															
Nysson trimaculatus (Rossius)	N															
Oxybelus uniglumis (L.)														/		
Passaloecus corniger Shuckard																
Passaloecus gracilis (Curtis)																
Passaloecus singularis Dahlbom																
Pemphredon inornata Say																
Pemphredon lethifera (Shuckard)														/		
Pemphredon lugubris (Fab.)													/		/	
Pemphredon morio Vander Linden	N															
Philanthus triangulum (Fab.)	RDB2* (R)															
Psenulus concolor (Dahlbom)																
Psenulus pallipes (Panzer)																
Psenulus schencki (Tournier)	N															
Rhopalum clavipes (L.)																
Rhopalum coarctatum (Scopoli)																
Spilomena beata Blüthgen	R															
Spilomena troglodytes (Vander Vinden)																
Stigmus solskyi Morawitz																
Tachysphex pompiliformis (Panzer)	R															
Trypoxylon attenuatum Smith																
Trypoxylon clavicerum Lepeletier & Serville																
Trypoxylon figulus (L.) 's.s.'																
Trypoxylon 'figulus s.l.'																
Apidae																
Andrena apicata Smith	N															
Andrena bicolor Fab.																
Andrena bucephala Stephens	N, Calc															
Andrena chrysosceles (Kirby)																

(continued)